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Date: June 17th, 2022

SUBJECT: Petition for exemption from 14 CFR §33.27(f)(6)

RELATED REGULATION:

14 CFR §33.27(f)(6) at Amendment 33-31 and subsequent

(f) Failure of a shaft section may be excluded from consideration in determining the highest overspeed that would result from a complete loss of load on a turbine rotor if the applicant:

[...]

(6) does not exclude the entire shaft.

ISSUE:

Exclusion of entire High Pressure (HP) rotor shaft system comprising the HP Turbine (HPT) and HP Compressor (HPC) stubshafts creates a non-compliance with 14 CFR §33.27(f)(6) at Amendment 33-31 for the Pratt & Whitney Canada PW127XT engine models.

BACKGROUND:

The PW127XT is a series of three (3) new engine models in the PW100 engine family. These 3 models (PW127XT-M / PW127XT-N and PW127XT-L) are a continuation of the PW127 family of engines and as such, are derivatives of the PW124 engine. The Changed Product Rule (CPR) assessment has determined the changes to be non-significant. These 3 engine models will be used in derivatives of the ATR42 & 72 aircraft and are designed as “drop in” replacements for PW127E/F/M/N engines, retaining the same power and limitations. However, the new PW127XT engines feature reduced fuel consumption and reduced direct maintenance costs (DMC) through increased time between overhauls (TBO).

In order to achieve these goals, design changes were made to the compressor and turbine rotors and blades, bearings, housings and externals components. The design changes to the HPT blades, for which life extension was intended, required a redesign of the HPT area, including the bearing housing, the blade cooling air feed system and the turbine disc and associated cover

plates. In introducing these changes, the opportunity was taken to “design out” known failure modes related to the HPT stubshaft and retaining bolts.

More specifically, three (3) design changes in the HPT area were addressed:

- 1- An integral HPT stubshaft was created where the turbine disc and shaft were combined into one component, replacing the existing stubshaft and retaining nut (item 2). The HPC rotor already had an integral stubshaft;
- 2- The HPT stubshaft retention nut was removed (due to item 1); and
- 3- The retention bolts holding the stubshaft and rear HPT seal to the high pressure turbine rotor were eliminated.

Design changes 1 & 3 above were specifically made to address field issues. The new integrated stubshaft design (item 1) separated the labyrinth seal fin function from the stubshaft, thereby eliminating the potential for rubbing on static structures and ensuing shaft damage. This also allowed the elimination of the stubshaft retention bolts (item 3).

Removal of the existing HPT stubshaft and related retention nut (items 1 & 2) led to the introduction of a long HPT shaft clamping nut which spans across the entire length of the HPT disc. This shaft clamping nut is not a torque carrying component and as such is not part of the HP rotor shaft system and is not subject to this exemption. This new arrangement created a direct connection between the HPT and the HPC without the need for intermediate parts to carry the torque load, and thereby creating a connection entirely made of life-limited parts (LLP) designed to the integrity requirements of §33.70. The new configuration significantly reduces the space available at the HPT bore to design a disc with sufficient strength to resist burst at the terminal speed due to loss of load, despite the use of higher strength material. This higher strength material has been used in previous P&WC engine applications.

For reference, the Transport Canada certification basis for the new engine models was established as follows:

AWM Chapter 533 (Aircraft Engines) at Change 533-9, published on December 30, 2008, which is equivalent to 14 CFR part 33 up to and including Amendment 33-24, except for paragraph 533.27;

AWM Chapter 533 (Aircraft Engines) paragraph 533.27 at Change 533-13, published on July 13, 2014, which is equivalent to 14 CFR part 33 up to and including Amendment 33-32;

PW127XT Exemption NCR-054-2021 Loss of Load 533.27(f)(6);

14 CFR §33.27 Turbine, Compressor, Fan, and Turbosupercharger Rotors Overspeed specifies requirements for overspeed capacity of rotors, which includes loss of HPT load due to decoupling from the HPC. As a result of the design changes (items 1-3), full compliance to the requirements of §33.27 for rotor overspeed with respect to loss of load is not possible for the reason described above. However, if it were possible to exclude the HP rotor shaft system, i.e., the direct connection between the HPT and HPC rotors, from failure consideration because of their inherent integrity as LLPs, compliance to §33.27 could be demonstrated. This is

complicated by the fact that there are no provisions in §33.27 Amendment 24 to address the exclusion of HP rotor shaft system.

14 CFR §33.27(f) introduced at Amendment 31 includes a provision to exclude a shaft section from the determination of the highest overspeed that could result from a complete loss of load on a turbine rotor, under a number of conditions. Thus, for the PW127XT certification basis, P&WC would elect to comply with §33.27 at Amendment 32. Paragraphs 33.27(f)(1) through (5) provide the requirements that allow application of the exclusion. However, paragraph 33.27(f)(6) restricts the use of the exclusion to only a portion of the shaft. In the case of the PW127XT, due to the short distance between the HPC and HPT rotors and the limited numbers of torque carrying parts involved (2), the complete HP rotor shaft system is proposed to be excluded.

By a FAA letter dated March 18, 2015, an Aerospace Industries Association (AIA) advisory group was formed at FAA's request, through the Civil Aviation Regulatory & Safety Committee (CARS), Propulsion Sub-committee, with the mandate to determine whether there is a need for the FAA to change the overspeed regulations or guidance material related to shaft system failure in or around the turbine section of the engine, and if changes are necessary, to provide recommendations for changes to the overspeed regulations and guidance material. The FAA was particularly interested in evaluating the high pressure rotor within the mandate.

In May 2019, the AIA working group issued a report entitled "*Guidance on exclusion of a High Pressure Turbine shaft element, section, or system from failure consideration in determining the terminal High Pressure Turbine rotor speed in the event of a complete loss of load event*". The report defines the assessments that should be completed to substantiate an exclusion of elements of an HP rotor shaft system, including a complete shaft. The report applies to HP rotor shaft systems only and is based on FAA regulation 14 CFR 33.27 at Amendment 33-31.

Therefore, for the PW127XT engine models, this request seeks an exemption for the HP rotor shaft system from the requirement of 14 CFR §33.27(f)(6) based on the AIA report mentioned above. P&WC's assessment shows that the requirements identified in the AIA report can be met.

Furthermore, Pratt & Whitney Canada Corp. believes that the supporting argument and the assessment of maintaining safety and public interest below justify this exemption request.

(1) PUBLIC INTEREST:

The exemption is in the public interest as it is an enabler for the improved engine design which addresses safety, environmental, commercial considerations and benefits to the economy.

(a) Safety considerations:

The PW127XT introduces improvement on field issues that were identified on the legacy engine models, thereby improving the safety and reliability of the engine. Known failure modes that could potentially expose the rotor to loss of load (fracture of stubshaft and retaining bolts) are eliminated from the design, enhancing safety margins. It should be noted that the failure modes for the legacy engine models did not lead to hazardous conditions.

(b) Environmental considerations:

The exemption would allow the introduction of new engines with lower fuel consumption, thereby reducing actual emissions released in the atmosphere. It would also be an enabler to increased TBO limits for the engine, reducing the number of parts consumed over the life of the engine and the overall resources consumption (energy, material).

(c) Commercial considerations:

The lower fuel consumption and reduced part replacement would directly lead to a reduction of the aircraft operational cost to the operators.

(d) Benefits to economy:

The PW127XT models further extend the PW100 engine family long history by remaining a competitive engine in the marketplace thus maintaining sales of this product, mainly in foreign countries. This in turn maintains jobs, community wealth and government revenue.

(2) AVIATION SAFETY:

The following factors ensure aviation safety is not adversely affected:

- (a) There are only two torque carrying components comprising the HP rotor shaft system (the new shaft clamping nut is not in the torque load path): the integral stubshafts of the HPC and HPT rotors. Both of these rotors are life limited parts (LLP) and are removed from service when the life is expired. Calculated lives for the stubshaft portion of these two components are much greater than their declared service life. Therefore, the stubshafts have a very high reliability.
- (b) There are very few occurrences of HP rotor shaft decoupling on the PW100 engine family. All service difficulties were related to distress of the HPT stubshaft and/or retaining bolts, either as primary or secondary damage. These features are eliminated in the new design, and the shaft portion of the HPC and HPT are protected from contact with static structures by separate seal runners. Also, a newer and stronger material is used in the HPT rotor.
- (c) The new rotors are designed to meet the latest §33.70 requirements for LLPs, which includes damage tolerance principles. The prior design complied with the predecessor requirements (§33.14) and analysis principles, not including damage tolerance.

14 CFR §33.70 requires that component life limitations be declared in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness as required by §33.4 to mandate the removal of the parts before a hazardous condition may occur. §33.70 also introduces the concept of engineering, manufacturing, and service management plans.

The engineering plan provides the framework that supports the design, analytical, and development testing activities which allow the determination of component life. §33.70 also requires that damage tolerance analysis be performed to ensure that a minimum crack propagation life be achieved in the parts. This work is performed with methodologies approved by Transport Canada.

The manufacturing plan identifies the specific manufacturing constraints necessary to consistently produce each engine life-limited part within the attributes required by the engineering plan.

The service management plan defines in-service processes for maintenance and the limitations to repair each engine life-limited part that will maintain attributes consistent with those required by the engineering plan. These processes and limitations are part of the Instructions for Continued Airworthiness.

- (d) The design follows the assessment guidance provided by the the Aerospace Industries Association (AIA) working group guidance report titled "*Guidance on exclusion of a High Pressure Turbine shaft element, section, or system from failure consideration in determining the terminal High Pressure Turbine rotor speed in the event of a complete loss of load event*" and will form part of Transport Canada AWM 533.27 compliance record for the HP rotor shaft system. The AIA guidance specifically states the following:

"If all elements or sections of the shaft system comply with the assessments, then the whole shaft system may be excluded from consideration in determining the highest overspeed that would result from a complete loss of load on a HPT rotor".

P&WC wants to exercise the privileges of the exemption outside the United States as the aircrafts the engines are installed in (ATR42 & 72) are sold in numerous countries. As mentioned before, an exemption was already granted by Transport Canada.

Summary for publishing in Federal Register

Pratt & Whitney Canada seeks an exemption for its PW127XT-M, PW127XT-N and PW127XT-L engine models HP rotor shaft system to the requirement of 14 CFR §33.27(f)(6) (Amendment 33-31 and subsequent) which requires that the entire shaft not be excluded from the loss of load case of the overspeed determination. Specifically, P&WC is proposing that the FAA allows the exclusion of the only 2 components that make up the shaft system, based on the AIA document "*Guidance on exclusion of a High Pressure Turbine shaft element, section, or system from failure consideration in determining the terminal High Pressure Turbine rotor speed in the event of a complete loss of load event*".